

Prediction of Weakest Area and Line in IEEE 57 Bus System

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ABSTRACT: This paper presents a method of finding weakest area and line in complex power system network which comprises of a 57 bus and 6 generator system (IEEE 57-bus system). The case studies have been analyzed by considering the effect of generator outages and other abnormal loadings. This method uses a voltage stability index parameter to decide the maximum loading of the line beyond which line gets voltage collapse causing the surrounding area to get diverged from its normal stable point... The parameter called basic line stability index is derived and used to analyze whether the weakest area and the line in the complex network is far away from voltage collapse point or not. This index gives the idea about the voltage divergence point of the line and area of the system.

The simulation results have been obtained by MATLAB programming for a 57 bus system. The main aim of using this method is to help the operators at load control centers to avoid blackouts which are serious problems of modern power system network.

KEYWORDS: Basic line stability index, Divergence, Blackouts, Maximum loadability, Generator outages

ABBREVIATION: Blsi= basic line stability index.

I. INTRODUCTION

The methods to avoid problems of voltage collapse has been being observed in many areas in the world and has been being investigated for past one decade[2-4]. The major disturbance in power system network is voltage stability related blackouts. This abnormal disturbance is due to overloading and line outages. Maintaining Voltage stability has become a challenging and focusing area for power utilities under abnormal changes in power system [1], [5-8]. This method gives an idea in such a way that load operator can anticipate the problem thus avoids the blackouts and related problems. This paper anticipates a stability index that is Blsi (basic line stability index) for all lines in the given IEEE 57 bus system under some disturbances and gives indication and alarm signal to load control centre that particular line and area get diverged.

II. RELATED WORK

Voltage instability was the most significant problem as it destructs the entire power network making the network to be isolated from other stable network. This problem was analysed by so many researchers to give their contribution in avoiding the problems pertaining to voltage instability. Some of the methods and techniques that were contributed by researchers had been used only in off-line based applications. But off-line applications would not give real time status so as to trace the system health. Change in climatic conditions affects the power flow in the line. We can predict this by employing the methods which are best suited for on-line applications. So many methods that had been adopted in finding the solution towards voltage instability problems were discussed in [9-13]. The method that is introduced in this paper also best suited for on-line application making it as a efficient method to trace electrical quantities in the system in real time manner

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III. PROPOSED METHODOLOGY

The concept of basic line stability index is understood by the following theory and derivation. For example if we consider the transmission line (m-n) in the network which is to be monitored, the parameters to be considered for deriving the basic line stability index for the line(m-n) is given below.

- 1). a voltage magnitude V_m at a sending bus m, of each transmission line (m-n),
- 2). a voltage magnitude V_n at a receiving bus n of each transmission line (m-n),
- 3). a sending bus voltage angle δ_m ,
- 4). a receiving bus voltage angle δ_n ,
- 5). a line power flow $P_{mn} + jQ_{mn}$ charging reactive power added at the receiving bus,
- 6). a line power flow $P_m + jQ_m$ with a charging reactive power added at sending bus,
- 7). $P_m + jQ_m^*$ the line power flow after the charging reactive power at the sending bus m,
- 8). $P_{mn} + jQ_{mn}^*$ the line power flow before the charging reactive power at the receiving bus n,
- 9). $R_{mn} + jX_{mn}$ is the line impedance
- 10). Y indicates half of the grounding admittance of the line (m-n).

The line power flow equation of $P_{mn} + jQ_{mn}^*$ can be expressed as

$$P_{mn} + jQ_{mn}^* = (V_n \angle \theta_n)^* \left(\frac{V_m \angle \theta_m - V_n \angle \theta_n}{R_{mn} + jX_{mn}} \right)^* \tag{1}$$

Where * symbol indicates conjugate operation for complex number

Solving (1) into real and imaginary parts

$$R_{mn}P_{mn} + X_{mn}Q_{mn}^* = -V_n^2 + V_m V_n \cos\theta_{nm} \tag{2}$$

$$R_{mn}Q_{mn}^* - X_{mn}P_{mn} = V_m V_n \sin\theta_{nm} \tag{3}$$

WHERE $\theta_{nm} = \theta_n - \theta_m$

Eliminating the angle difference θ_{nm} from (2) and (3), we get following double quadratic equation with V_n^2 as unknown variable

$$V_n^4 + 2[R_{mn}P_{mn} + X_{mn}Q_{mn}^* - (\frac{V_m^2}{2})]V_n^2 + (R_{mn}^2 + X_{mn}^2)((P_{mn})^2 + (Q_{mn}^*)^2) = 0 \tag{4}$$

When the discriminant of double quadratic equation(4) is greater than or equal to the value zero.

Mathematically it can be written as

$$[R_{mn}P_{mn} + X_{mn}Q_{mn}^* - (\frac{V_m^2}{2})]^2 - (R_{mn}^2 + X_{mn}^2)((P_{mn})^2 + (Q_{mn}^*)^2) \geq 0 \tag{5}$$

The equation (4) will have two solutions given by

$$V_n^2 = -[R_{mn}P_{mn} + X_{mn}Q_{mn}^* - (\frac{V_m^2}{2})] \pm \sqrt{[R_{mn}P_{mn} + X_{mn}Q_{mn}^* - (\frac{V_m^2}{2})]^2 - (R_{mn}^2 + X_{mn}^2)((P_{mn})^2 + (Q_{mn}^*)^2)} \tag{6}$$

As $(R_{mn}^2 + X_{mn}^2)((P_{mn})^2 + (Q_{mn}^*)^2) \geq 0$, it is obvious that

$$\sqrt{[R_{mn}P_{mn} + X_{mn}Q_{mn}^* - (\frac{V_m^2}{2})]^2 - (R_{mn}^2 + X_{mn}^2)((P_{mn})^2 + (Q_{mn}^*)^2)} \leq [R_{mn}P_{mn} + X_{mn}Q_{mn}^* - (\frac{V_m^2}{2})]$$

So that V_n will have two positive real number solutions from (6), the equation(7) must have

$$[R_{mn}P_{mn} + X_{mn}Q_{mn}^* - (\frac{V_m^2}{2})] \leq 0 \tag{7}$$

Therefore equation (5) may be re written as

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Vol. 3, Issue 6, June 2014

$$Blsi = \frac{V_m^2}{\sqrt{R_{mn}^2 P_{mn}^2 + X_{mn}^2 Q_{mn}^2 + \sqrt{(R_{mn}^2 + X_{mn}^2)(P_{mn}^2 + Q_{mn}^2)}}} \quad (8)$$

(where Blsi represents basic line stability index).

From the derived index in Equation (8), the following observations are found:

1. The Blsi should be larger than or equal to the value 1.0(one), that indicates the receiving bus voltage V_n will have a mathematical solution(real value) that is operational in real life.
2. The Blsi can be used to anticipate the status of the weak lines (branches) and weakest areas in a system.
3. Whichever the line is approaching to the value 1 or less than it ,that particular line is considered to be diverged from its normal operating state.

IV. SIMULATION AND RESULTS

This method is applied for practical IEEE 57 test bus system.This IEEE 57 bus system is well known as six machines (generators) and 57 bus system. Various conditions like increment in loading levels at PQ buses, increment in generations at PV buses and various generator outages were considered to check the basic line stability index(Blsi) which gives the idea about system divergence point from its Stable operating point.

Single line diagram of IEEE 57 bus and 6 generator test system with areas divided is shown in FIG 1.

A.CASE

DURING LOAD INCREMENT AT BUS 57,BLSI OF LINES IN 3 DIFFERENT AREAS OBSERVED AS FOLLOWS

I. TABLE

AREA	BLSI OF LINES IN DIFFERENT AREAS DURING LOAD INCREMENTS AT BUS 57	
AREA1	BLSI OF LINE(22-23)	LOAD(IN MW)
	1.5450	63
	1.1627	73.7
AREA2	0.2137	80.4
	2.7315	63
	0.6557	73.7
AREA3	0.5264	80.4
	BLSI OF LINE(37-39)	LOAD (IN MW)
	4.0593	63
	0.3853	73.7
	0.1236	80.4

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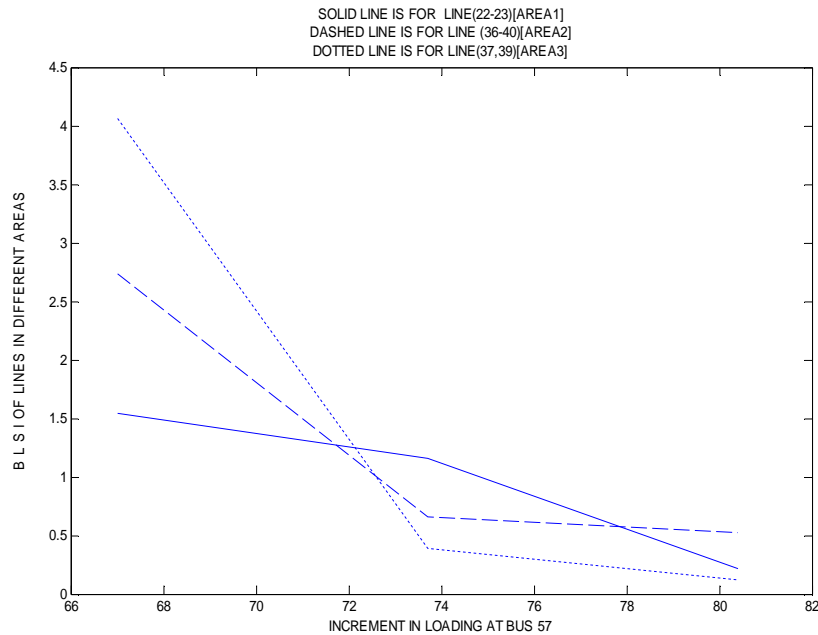


FIG2. BLSI OF 3 DIFFERENT LINES(DURING LOAD INCREMENT AT BUS 57)

OBSERVATION

Before 72 MW loading, the line (22-23) in area 1 is more likely to get collapse than the lines in other areas.

After 72 MW loading level, the line(36-40) in area2 is more likely to get collapse than the lines in other areas.

B.CASE

DURING GENERATOR INCREMENT AT BUS 2, BLSI OF LINES IN 3 DIFFERENT AREAS

II. TABLE

AREA	BLSI OF LINES IN DIFFERENT AREAS DURING GENERATOR INCREMENTS AT BUS 2	
AREA1	BLSI OF LINE(23-22)	LOAD(IN MW)
	1.4364	63
	0.0965	73.7
AREA2	BLSI OF LINE(36-40)	LOAD(IN MW)
	5.7442	63
	0.1313	73.7
AREA3	BLSI OF LINE(47-48)	LOAD (IN MW)
	1.6565	63
	0.2622	73.7
	0.2464	80.4

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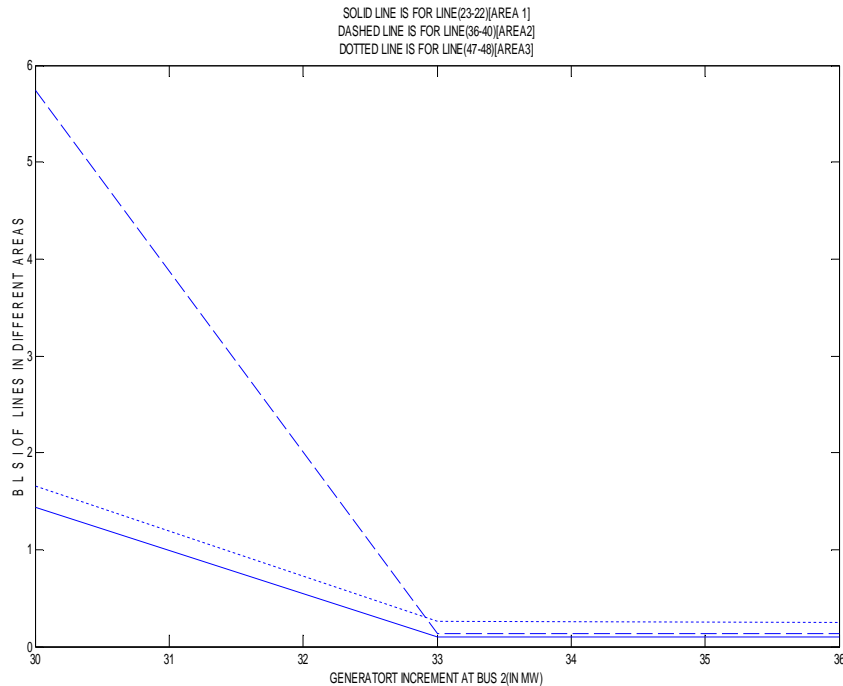


FIG3.BLSI OF 3 DIFFERENT LINES (DURING GENERATOR INCREMENT AT BUS 2)
OBSERVATION

BEFORE AND AFTER 33MW,THE LINE(23-22) WHICH IS IN THE AREA 1 IS MORE LIKELY TO GET COLLAPSE THAN THE OTHERS .IT IS OBSERVED THAT IN ALL CONDITIONS,AREA1 IS WEAKEST AREA..
C.CASE

DURING LOAD INCREMENT AT BUS 57,BLSI OF LINES IN 3 DIFFERENT AREAS OBSERVED AS FOLLOWS(WITH GENERATOR OUTAGE AT BUS 3 IS CONSIDERED)

III. TABLE

AREA	BLSI OF LINES IN DIFFERENT AREAS DURING LOAD INCREMENTS AT BUS 57(WITH GENERATOR OUTAGE ATBUS 3)	
AREA1	BLSI OF LINE(38-22)	LOAD(IN MW)
	1.1247	63
	0.6108	73.7
AREA2	BLSI OF LINE(32-33)	LOAD(IN MW)
	2.8430	63
	1.7491	73.7
AREA3	BLSI OF LINE(39-37)	LOAD (IN MW)
	4.1334	63
	0.0168	73.7
	0.0142	80.4

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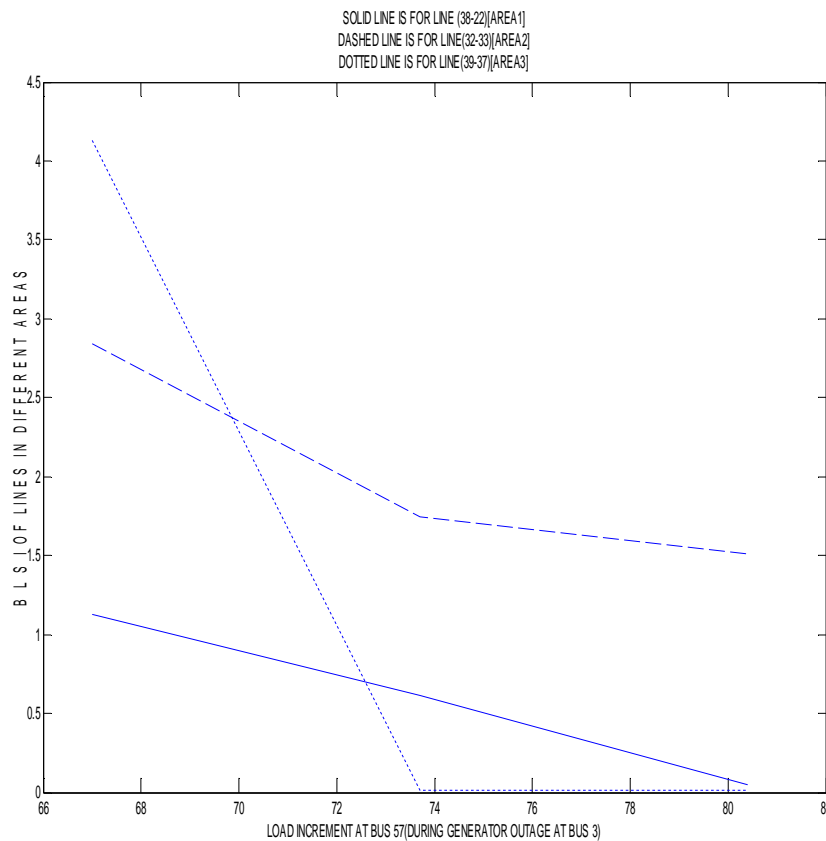


FIG4.BLSI OF DIFFERENT LINES (DURING LOAD INCREMENT AT BUS 57 AND GENERATOR OUTAGE AT BUS 3)

OBSERVATION

BEFORE 73 MW, AREA1 IS WEAKEST AREA

AFTER 73 MW, AREA3 IS THE WEAKEST AREA.

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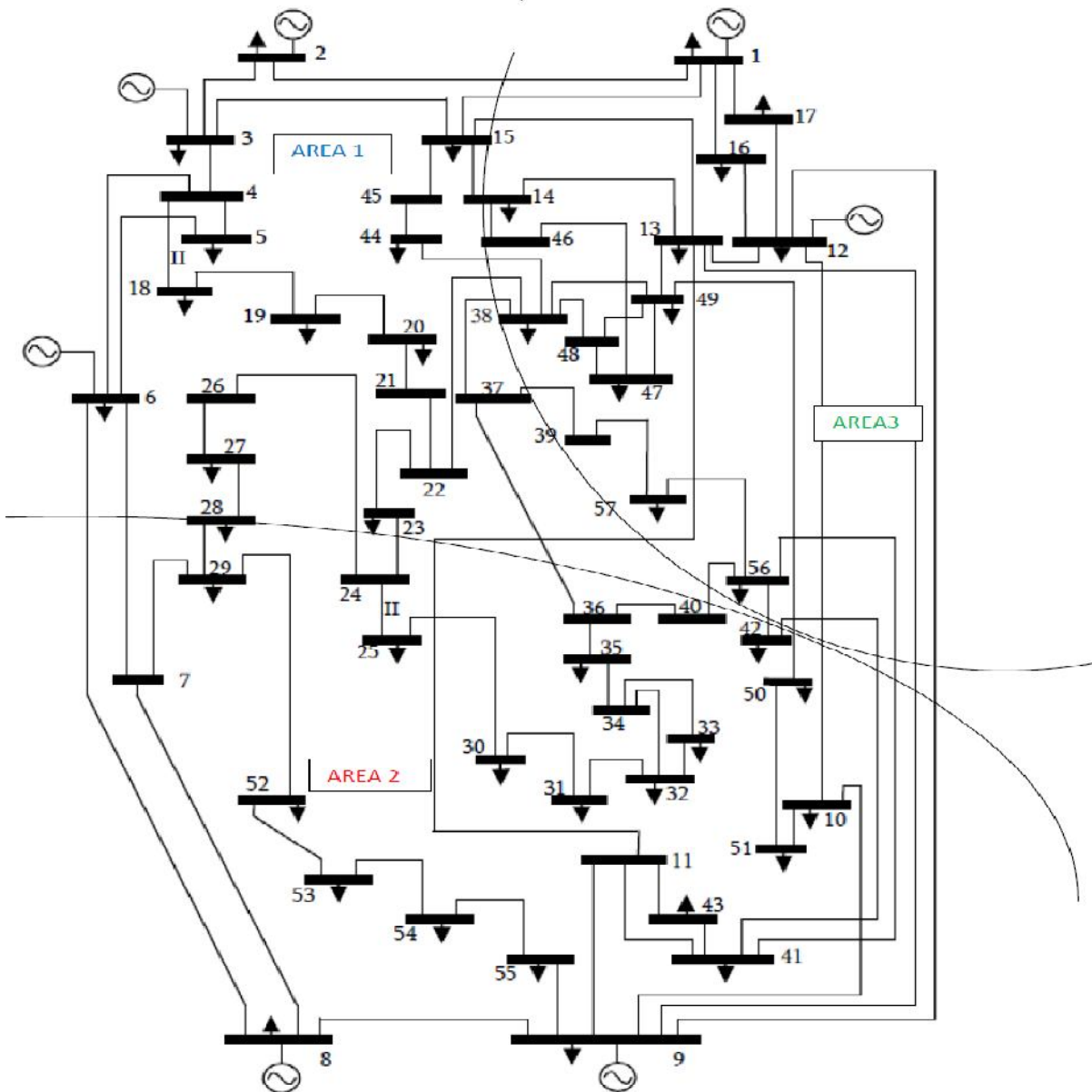


FIG1.SINGLE LINE DIAGRAM OF IEEE 57 BUS(WITH AREA DIVIDED)

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(An ISO 3297: 2007 Certified Organization)

Vol. 3, Issue 6, June 2014

IV. CONCLUSION

Thus We have implemented a method called stability index method in a system comprises of 57 buses and 6 generators to observe the voltage divergence point of each power line in the system. This method will be helpful to power utilities and operators at load control centres to monitor the complex system with corrective actions at specific locations where the line get easily diverged from normal state. This method also predicts the weakest region and the weakest line in IEEE 57 bus system.

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BIOGRAPHY

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